SOE 9: Focus Session: Critical Transitions in Society, Economy, and Nature (joint session SOE/DY)

Organizers: Fakhteh Ghanbarnejad (Robert Koch-Institut), Diego Rybski (Potsdam Institute for Climate Impact Research)

Time: Wednesday 9:30–11:45 Location: ZEU 260

Topical Talk SOE 9.1 Wed 9:30 ZEU 260

Many universality classes in an interface model restricted to non-negative heights — •Peter Grassberger[1], Deepak Dhar[2], and Pradeep Mohanty[3] — [1]JSC, Forschungszentrum Jülich, D-52425 Jülich, Germany — [2]Indian Institute of Science Education and Research, Pune, 411 008, India — [3]Indian Institute of Science Education and Research - Kolkata Mohanpur, 741 246, India

We present a simple 1-d stochastic model with two control parameters and a rich zoo of phase transitions. At each (discrete) site x and time t, there is an integer $n(x,t)$ that satisfies a linear interface equation with added random noise. Depending on the control parameters, this noise may or may not satisfy detailed balance, so that the model is – for suitable initial conditions – in the Edwards-Wilkinson (EW) or in the Kardar-Parisi-Zhang (KPZ) universality class. But in contrast to these, there is also a constraint $n(x,t) \geq 0$. Points x where $n > 0$ on one side and $n = 0$ on the other are called "fronts". These fronts can be "pushed" or "pulled", depending on the control parameters. For pulled fronts, the lateral spreading is in the directed percolation (DP) universality class, while it is of a novel type for pushed fronts, with yet another novel behavior in between. In the DP case, the activity at each active site can in general be arbitrarily large, in contrast to previous realizations of DP. Finally, we find two different types of transitions when the interface detaches from the line $n = 0$ (with $\langle n(x,t)\rangle \to const$ on one side, and $\to \infty$ on the other), again with new universality classes. We also discuss a mapping of this model onto a directed Oslo rice pile model in specially prepared backgrounds.

Topical Talk SOE 9.2 Wed 10:00 ZEU 260

Nonequilibrium phase transitions and critical behavior in networks — •Eckehard Schöll — Institut für Theoretische Physik, TU Berlin — Potsdam Institute for Climate Impact Research — Bernstein Center for Computational Neuroscience Berlin

Phase transitions in nonlinear dynamical systems far from thermodynamic equilibrium have been investigated since the 1970s and 1980s, and concepts from thermodynamics and statistical physics have been applied to describe self-organization, spatio-temporal pattern formation, phase coexistence, critical phenomena, and first and second order nonequilibrium phase transitions. Much more recently, phase transitions and critical phenomena have been studied in dynamical networks, where synchronization transitions may arise, giving birth to a plethora of partial synchronization patterns and complex collective behavior, with applications to many natural, socioeconomic, and technological systems. We review these developments, and draw some connections of tipping transitions, explosive synchronization, nucleation, critical slowing down, critical exponents, etc. with nonequilibrium thermodynamics. [1] Tumash, L., Olmi, S. and Schöll, E., Effect of disorder and noise in shaping the dynamics of power grids, Europhys. Lett. 123, 20001 (2018). [2] Berner, R., Sawicki, J., Thiele, M., Löser, T. and Schöll, E., Critical parameters in dynamic network modeling of sepsis, Front. Netw. Physiol. 2, 904480 (2022). [3] Fialkowski, J., Yanchuk, S., Sokolov, I. M. , Schöll, E., Gottwald, G. A. and Berner, R., Heterogeneous nucleation in finite size adaptive dynamical networks, arXiv:2207.02939 (2022).

15 min. break

Topical Talk SOE 9.3 Wed 10:45 ZEU 260

Critical transition to monsoon: statistical physics principles of monsoon forecasting — •Elena Surovyatkina — Potsdam Institute for Climate Impact Research (PIK), Potsdam, Germany — Space Research Institute of the Russian Academy of Sciences (IKI), Moscow, Russia

Numerical weather models are limited to forecasting the weather for up to 5 days in the future. A fundamental problem lies in the chaotic nature of the spatial differential equations used to simulate the atmosphere. The limitations of current prediction models prevent further progress.

I present a recently developed approach fundamentally different from the numerical weather and climate models. It is based on statistical physics principles and recently discovered spatial-temporal regularities (or teleconnections between Tipping Elements) in a monsoon system.

First, I begin with evidence in observational data that the transition from pre-monsoon to monsoon is a critical transition. Second, I show how to detect the Tipping elements in the spatial organization of monsoon using the phenomenon of critical growth of fluctuations. Third, I explain how the regularities between the Tipping Elements allow predicting the upcoming monsoon onset and withdrawal for 40 and 70 days in advance, respectively.

Furthermore, I present the results of retrospective tests from 1951 to 2015, which show 73 % success for monsoon onset and 84 % for a withdrawal date. Remarkably, that forecasts of future monsoons showed to be successful already seven years in a row, 2016-2022.

SOE 9.4 Wed 11:15 ZEU 260

Synchronization-desynchronization transitions in neural networks — •Anna Zakharova — BCCN Berlin, Germany

Synchronization of neurons is believed to play a crucial role in the brain under normal conditions, for instance, in the context of cognition and learning, and under pathological conditions such as Parkinson's disease or epileptic seizures. In the latter case, when synchronization represents an undesired state, understanding the mechanisms of desynchronization is of particular importance. In other words, the possible transitions from synchronized to desynchronized regimes and vice versa should be investigated. It is known that such dynamical transitions involve the formation of partial synchronization patterns, where only one part of the network is synchronized. The most prominent example is given by chimera states [1]. In the present talk, we discuss an alternative scenario. We show how the so-called solitary states in networks of coupled FitzHugh-Nagumo neurons can lead to the emergence of chimera states. By performing bifurcation analysis of a suitable reduced system in the thermodynamic limit we demonstrate how solitary states, after emerging from the synchronous state, become chaotic in a classical period-doubling cascade [2].

[1] A. Zakharova, Chimera Patterns in Networks: Interplay between Dynamics, Structure, Noise, and Delay, Understanding Complex Systems (Springer, Cham, 2020) doi: 10.1007/978-3-030-21714-3

[2] L. Schülen, A. Gerdes, M. Wolfrum, A. Zakharova, Solitary routes to chimera states, Phys. Rev. E Letter 106, L042203 (2022) doi: 10.1103/physreve.106.l042203

SOE 9.5 Wed 11:30 ZEU 260

The war in Ukraine, a statistical analysis — •Juergen Mimkes — Physics Department, Paderborn University

War is a serious disruption of normal social order and may be analyzed by statistics. In homogeneous systems the Lagrange function depends on two Lagrange factors: L (λ, p). In physics, they are mean energy or temperature (λ) and pressure (p). In politics, they are mean capital or standard of living (λ) and military pressure (p). The factors (λ),(p) determine the state or phases of a system. In materials we have solid, liquid, gas, in politics autocratic, democratic, global. Different phases can only coexist at equilibrium in the phase diagram. Outside of equilibrium water and ice cannot coexist in close contact, water is melting ice (climate crisis). Outside of equilibrium democracy and autocracy cannot coexist in close contact, democracy is *melting* autocracy since the Marshall plan in 1947. Accordingly, there has been an aggressive reaction by the autocracy: DDR 1953, Hungary 1956, CSR 1968, Ukraine 2014. There is no chance for peace, unless one party vanishes. The only solution to keep hot and cold together is a thermos, and to keep democracy and autocracy side by side is a new iron curtain like in Korea or Europe (1961 to 1989).